



U.S. NUCLEAR REGULATORY COMMISSION

# STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

## 3.13 THREADED FASTENERS<sup>1</sup>

### REVIEW RESPONSIBILITIES

Primary - Materials and Chemical Engineering Branch (EMCB)

Secondary - None

### I. AREAS OF REVIEW

- A. The purpose of the staff's review in this area is intended to ensure that threaded fasteners are designed, procured, installed, inspected, tested, and maintained so that safety-related components and structures containing the fasteners will perform their intended functions in a manner commensurate with the importance of the safety function to be performed.<sup>2</sup>
- B. The review covers the following general requirements described in 10 CFR Part 50. These general requirements provide the sources of the acceptance criteria related to threaded fasteners within the staff's area of review.
  - 1. 10 CFR 50.55a, "Codes and Standards," requires (in part) that:
    - a. Structures, systems, and components (SSCs) must be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed;
    - b. Components of the reactor coolant pressure boundary (RCPB) must meet the requirements for Class 1 components in Section III of the American Society of Mechanical Engineers (ASME) Code;

DRAFT Rev. 0 - April 1996

---

### USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants. These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required. The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

---

- c. Quality Group B components covered in Regulatory Guide 1.26 must meet the requirements for Class 2 components in Section III of the ASME Code;
  - d. Quality Group C components covered in Regulatory Guide 1.26 must meet the requirements for Class 3 components in Section III of the ASME Code; and
  - e. ASME Code Class 1, 2, and 3 components must be designed and be provided with access to facilitate the performance of inservice inspection and testing.<sup>3</sup>
2. 10 CFR 50.60, "Acceptance Criteria For Fracture Prevention Measures For Lightwater Nuclear Power Reactors For Normal Operation," requires that the requirements of Appendix G to 10 CFR Part 50, "Fracture Toughness Requirements," be met unless an exemption is granted based upon proposed alternatives. Appendix G applies to bolting and fastener materials in pressure-retaining components of the reactor coolant pressure boundary with specified minimum yield strengths not over 896 MPa (130,000 psi). Appendix G describes tests and other requirements applicable to these items.<sup>4</sup>
  3. General Design Criterion 1 (GDC 1), "Quality Standards and Records," requires (in part) that:
    - a. SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed;
    - b. A quality assurance (QA) program shall be established and implemented to provide adequate assurance that these SSCs will satisfactorily perform their safety functions; and
    - c. Appropriate records for the design, fabrication, erection, and testing of SSCs important to safety shall be maintained by the licensee.<sup>5</sup>
  4. General Design Criterion 2 (GDC 2), "Design Bases for Protection Against Natural Phenomena," requires (in part) that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, tsunami, and seiche without loss of capability to perform their safety functions.<sup>6</sup>
  5. General Design Criterion 4 (GDC 4), "Environmental and Dynamic Effects Design Bases," requires (in part) that SSCs important to safety be designed to accommodate the effects of, and be compatible with, environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents (LOCAs).<sup>7</sup>

6. General Design Criterion 14 (GDC 14), "Reactor Coolant Pressure Boundary," requires (in part) that the RCPB be designed, fabricated, erected, and tested in a manner that provides assurance of an extremely low probability of abnormal leakage, rapidly propagating failure, or gross rupture.<sup>8</sup>
7. General Design Criterion 15 (GDC 15), "Reactor Coolant System Design," requires (in part) that the reactor coolant system (RCS) and associated auxiliary, control, and protection systems be designed with sufficient margin to ensure that the design conditions of the RCPB are not exceeded during any condition of normal operation, including anticipated operational occurrences.<sup>9</sup>
8. General Design Criterion 30 (GDC 30), "Quality of Reactor Coolant Pressure Boundary," requires (in part) that:
  - a. Components that are part of the RCPB be designed, fabricated, erected, and tested to the highest quality standards practical; and
  - b. Means be provided for detecting and, to the extent practical, identifying the location of reactor coolant leakage.<sup>10</sup>
9. General Design Criterion 31 (GDC 31), "Fracture Prevention of Reactor Coolant Pressure Boundary," requires (in part) that:
  - a. The RCPB be designed with sufficient margin to ensure that when stressed under operating, maintenance, testing, and postulated accident conditions the boundary behaves in a nonbrittle manner and the probability of rapidly propagating fracture is minimized; and
  - b. The design reflect consideration of service temperatures and other conditions of the boundary material under operating, maintenance, testing, and postulated accident conditions, including the uncertainties associated with determining:
    - (1) Material properties;
    - (2) The effects of irradiation on material properties;
    - (3) Residual, steady state, and transient stresses; and
    - (4) Size of flaws.<sup>11</sup>
10. General Design Criterion 32 (GDC 32), "Inspection of Reactor Coolant Pressure Boundary," requires (in part) that components that are part of the RCPB be designed to permit:
  - a. Periodic inspection and testing of important areas and features to assess their structural leaktight integrity, and

- b. An appropriate material surveillance program for the reactor pressure vessel.<sup>12</sup>
- 11. Appendix B to 10 CFR Part 50, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Facilities," includes requirements applicable to threaded fasteners (reviewed under SRP Chapter 17) in the following subsections:
  - a. Part VIII, "Identification and Control of Materials, Parts, and Components";
  - b. Part X, "Inspection";
  - c. Part XI, "Test Control"; and
  - d. Part XV, "Nonconforming Materials, Parts, or Components."<sup>13</sup>
- C. The scope of the staff's review includes the following:
  - 1. Bolts, nuts, studs, washers, cap screws, machine screws, concrete anchors, hanger rods, U-bolts, and locking devices in seismic Category I SSCs, as defined in subsection C.1 of Regulatory Guide 1.29. Several issues related to threaded fasteners in general, or to certain types of threaded fasteners, are reviewed for other Standard Review Plan (SRP) sections, as described in the Review Interfaces subsection of this section.
  - 2. Bolts, nuts, studs, washers, cap screws, machine screws, concrete anchors, hanger rods, U-bolts, and locking devices in those portions of SSCs for which continued function is not required but where failure could reduce the functioning of any seismic Category I SSCs to an unacceptable safety level, or could cause incapacitating injury to occupants of the control room. (This category will be referred to hereafter as "SC I-related." See subsection C.2 of Regulatory Guide 1.29.)<sup>14</sup>
  - 3. Procedures and programs for each of the applications listed below:
    - a. Threaded fastener applications in the RCPB and RCS, including the following:
      - (1) Reactor head studs;
      - (2) RCS internals;
      - (3) RCPB pipe, pump, and valve flanges; and
      - (4) RCS pump and valve internal fasteners.

- b. Threaded fastener applications in pressure-retaining joints of seismic Category I components other than the RCPB or the RCS, including the following:
      - (1) Pipe, pump, and valve flanges; and
      - (2) Pump and valve internal fasteners.
    - c. Threaded fasteners for nonpressure-retaining applications of seismic Category I components and of seismic Category I component supports and structures:
      - (1) Component support hold-down fasteners, and
      - (2) Structural connections.
    - d. Threaded fastener applications in SC I-related SSCs:
      - (1) Pipe, pump, and valve flanges;
      - (2) Pump and valve internal fasteners;
      - (3) Component support hold-down fasteners; and
      - (4) Structural connections.<sup>15</sup>
  - 4. For the threaded fasteners and their applications cited in subsections I.C.1, I.C.2, and I.C.3, programs and procedures related to the following issues are reviewed:
    - a. Design
      - (1) The loading of threaded fasteners and the number of fasteners to resist specific load combinations are reviewed in accordance with the SRP section for the SSCs in which such fasteners are installed. [NOTE: There may be some redundancy in this SRP section regarding this topic. The review should be coordinated with the primary review branch for the particular SSC.]
      - (2) Fastener types (e.g., hex, cap screw, fine thread, coarse thread), nut types (e.g., hex, locknut), washer types (e.g., flat, lock, star, tab), and locking devices (e.g., wires, locking compounds) should be appropriate for the application.
      - (3) Fastener materials and interfacing materials should be compatible. Materials and properties, including the following, should be considered for both the fasteners and their joined parts:

- (a) Hardness;
  - (b) Fracture toughness;
  - (c) Corrosion considerations for dissimilar materials in contact;
  - (d) Lubricants, antiseize compounds, solvents, locking devices, and thread-locking compounds; and
  - (e) Insulating materials in proximity to or in contact with the fasteners.
- (4) Fatigue.
  - (5) Preload considerations.
  - (6) Temperature effects, creep, and relaxation.
  - (7) Erosion, corrosion (including boric acid corrosion), and the erosion/corrosion environment.
  - (8) Synergistic or combined effects related to items (1) through (7), above.

b. Installation

The review covers the adequacy of procedures and programs for installation of threaded fasteners relative to each of the following:

- (1) Tools;
- (2) Access;
- (3) Joint cleaning and lubrication;
- (4) Tightening, torquing, and tensioning techniques; and
- (5) Locking devices.

c. Procurement

The review covers the adequacy of procedures and programs for procurement of threaded fasteners relative to each of the following:

- (1) Specifications, and

- (2) Vendor reliability.

d. Quality Assurance

The review covers the adequacy of procedures and programs for quality assurance of threaded fasteners relative to each of the following (refer to SRP Chapter 17 for guidance):

- (1) Receipt, inspection, testing, storage, and handling;
- (2) Vendor audits;
- (3) Records; and
- (4) Training.

e. Maintenance

The review covers the adequacy of procedures and programs for maintenance of threaded fasteners and joints relative to each of the following:

- (1) Inservice inspection and testing;
- (2) Removal, refurbishment, cleaning, replacement, return-to-service; and
- (3) Troubleshooting.

f. Failure Analysis

The review covers the adequacy of procedures and programs for failure analysis of threaded fasteners and joints relative to each of the following:

- (1) Records and trends of failures or problems, and
- (2) Tracking and actions to resolve problems or failures as reported in industry.

g. Cognizant Engineer

The assignment and duties of a cognizant engineer or engineering group familiar with the problems and procedures involving threaded fasteners, as described in EPRI NP-5067, "Good Bolting Practices," are reviewed.<sup>16</sup>

5. Staff concerns related to threaded fasteners used in nuclear power plant applications are described in NUREG-0943, "Threaded-Fastener Experience in

Nuclear Power Plants," Generic Letter 91-17, "Bolting Degradation or Failure in Nuclear Power Plants," and NUREG-1339, "Resolution of Generic Safety Issue 29: Bolting Degradation or Failure in Nuclear Power Plants," and are summarized in Volume 1 of EPRI NP-5769, "Degradation and Failure of Bolting in Nuclear Power Plants." The staff reviews the procedures and programs developed by the applicant to ensure that these issues are addressed.<sup>17</sup>

6. The review covered by this SRP section supplements the reviews of SSCs in which the fasteners are installed. For the most part, fastener design (including loads, configuration, and arrangement) is covered by the review of the SSC in which the fastener is contained. However, some generic aspects of fastener design (e.g., preloading, material compatibility, corrosion) may also be reviewed under this SRP section.<sup>18</sup>

- D. A bibliography that includes pertinent references and standards is provided in Appendix A attached to this SRP section.<sup>19</sup>

### Review Interfaces

EMCB will coordinate other branch evaluations that interface with the overall review of threaded fasteners, as follows:<sup>20</sup>

1. The EMCB reviews subjects related to threaded fastener materials and materials in contact with threaded fasteners as part of its primary review responsibilities for SRP Sections 4.5.1, 4.5.2, 5.2.3, 5.3.1, 5.4.2.1, 6.1.1, 6.2.7, and 10.3.6.<sup>21</sup>
2. The Civil Engineering and Geosciences Branch (ECGB) reviews issues related to steel embedments (cast-in-place versus set in drilled holes) in concrete as part of its primary review responsibility for SRP Section 3.8.4 and other sections in the SRP 3.8 series.
3. The ECGB reviews issues related to prestressing connections, threaded connections for reinforcing bar splices or reinforcing bar anchorages, and threaded fasteners in steel structure connections as part of its review responsibility for sections in the SRP 3.8 series.<sup>22</sup>
4. The Mechanical Engineering Branch (EMEB) reviews issues related to seismic and quality group classification of threaded fasteners as part of its primary review responsibility for SRP Sections 3.2.1 and 3.2.2. (Threaded fasteners are classified as part of the component or support. See subsection I.C.3, above.)
5. The EMEB reviews issues related to piping, mechanical components, and mechanical and electrical component supports as part of its primary review responsibility for SRP Sections 3.6.1, 3.6.2, 3.9.2, and 3.9.3.<sup>23</sup>
6. The Quality Assurance and Maintenance Branch (HQMB) reviews programmatic aspects of QA, including those aspects regarding fasteners, as part of its primary review responsibility under SRP Chapter 17.<sup>24</sup>



For those areas of review identified as part of review under other SRP sections, the acceptance criteria and methods of application are contained in the referenced SRP sections.<sup>25</sup>

## II. ACCEPTANCE CRITERIA

The acceptance criteria are based on meeting the relevant requirements of 10 CFR 50.55a, 10 CFR 50.60, GDC 1, GDC 2, GDC 4, GDC 14, GDC 15, GDC 30, GDC 31, GDC 32, Appendix B of 10 CFR 50, and Appendix G of 10 CFR 50, as described in subsection I.B.

A. General acceptance criteria for all threaded fastener applications should include the following:

### 1. Installation

- a. Installation procedures should comply with EPRI NP-5067, Volume 1 or 2, as appropriate.
- b. Additional guidance on acceptable installation practices can be found in EPRI NP-5769 (as endorsed in Generic Letter 91-17 and NUREG-1339), standard textbooks such as Bickford (Ref. 29), EPRI NP-6316, and the Metals Handbook published by the American Society of Metals (ASM).
- c. To the extent practical, minimization of degradation and failure of support fasteners or embedments (e.g., resulting from fatigue, corrosion, inadequate installation, vibration, water hammer, or earthquake) should be emphasized in the installation procedures.

### 2. Procurement and Quality Assurance

- a. The applicant's overall QA program, including provisions for procurement, inspection, and testing of threaded fasteners, is reviewed by the HQMB as described in SRP Chapter 17.
- b. Guidance for detecting substandard or counterfeit threaded fasteners is provided in EPRI NP-5652, "Guideline for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications (NCIG-07)," as endorsed by NRC Generic Letter 89-02, "Actions to Improve the Detection of Counterfeit and Fraudulently Marketed Products," and NRC Generic Letter 91-05, "Licensee Commercial-Grade Procurement and Dedication Programs."
  - (1) Actions for detecting substandard or counterfeit products, including threaded fasteners, should be described in the applicant's procurement program.
  - (2) If threaded fasteners are obtained as commercial-grade items, the fasteners should be dedicated for use in safety-related applications

in accordance with the guidance offered in Generic Letters 89-02 and 91-05.

- c. The applicant's programs and procedures should include appropriate methods to verify threaded fastener attributes such as:
  - (1) Pertinent fastener dimensions (e.g., diameter, head height, width across corners, width across flats);
  - (2) Marking;
  - (3) Plating or coating; and
  - (4) Material properties (e.g., strength, chemistry, hardness, corrosion properties, surface condition).

These attributes should be verified by visual inspection and testing in accordance with a documented sampling plan.

- d. Sections NB-2610, NC-2610, and ND-2610 of the ASME Code describe the so-called "small products exclusion," which exempts bolting material (including studs, nuts, and bolts) from certain QA provisions. It should be noted that threaded fasteners must meet the remaining Code provisions, as well as all applicable staff requirements.
- e. The design requirements for threaded fasteners including the determination of acceptability of fastener threads is specified in ASME Section III, Table NB-3131-1. Table NB-3132-1 references ASME Standard B1.1 for determining thread acceptability and ASME Standard B1.1 permits the use of System 21 (GO/NO GO gages), System 22 (variable indicating gages), or more complex systems to determine thread acceptability. ASME Standard B18.3 is also referenced in ASME Code, Section III, Table NB-3132-1, and ASME Standard B18.3 requires the use of System 22 for determining thread acceptability. However, the ASME Code, Section III refers to ASME Section II where the fastener standards state that ASME Standard B18.3 is to be used for dimensions other than for the threads and that ASME Standard B1.1 is to be used for determining acceptability of the threads. Hence, procurement documents for fasteners may state that thread acceptability is to be determined using System 21, System 22, or more complicated methods and there are no requirements to use only System 22 in the nuclear industry.<sup>26</sup>

### 3. Failure Analysis

- a. Root cause analysis of threaded fastener or joint degradation and failure should be based on formal procedures and training.

- b. The applicant's programs and procedures should address threaded fastener problems identified by the staff and by industry, including those described in Generic Letter 91-17, NUREG-0943, and NUREG-1339.
- 4. Compatibility of Austenitic Stainless Steel Fasteners with Thermal Insulation
  - a. Reflective metal insulation is acceptable if the insulation material is compatible with both the fastener and the base material.
  - b. Nonmetallic insulation that complies with the criteria specified in Regulatory Guide 1.36, "Nonmetallic Thermal Insulation For Austenitic Stainless Steels," is acceptable. Requalification is not required when the ion concentrations described in Regulatory Guide 1.36, position C.3.b, deviate beyond the acceptable range on the low (conservative) side.
  - c. Preloading procedures should provide for establishing and maintaining acceptable values in areas of limited access.<sup>27</sup>
- B. Acceptance criteria for threaded fastener applications in the RCPB and RCS for areas of review described in subsection I.C include the following:
  - 1. The general requirements for systems and components containing such fasteners are described in 10 CFR 50.55a; 10 CFR 50.60; and General Design Criteria 1, 2, 4, 14, 15, 30, 31, and 32, as outlined in subsection I.B. Threaded fasteners in the RCPB and RCS are part of Quality Group A components, as described in Regulatory Guide 1.26, and thus must meet the specific requirements for ASME Code Class 1 components.
  - 2. Design requirements (including material selection and assurance of material compatibility) should include the following:
    - a. Threaded fastener and connection design should meet the requirements of ASME Code Section III, Subsection NB, and Appendix E. (Application of specific subsections and appendices of the ASME Code is summarized in EPRI NP-5769, Volume 2, Chapter 9.)
    - b. Bolting and fastener materials specified in paragraph I.C of Appendix G to 10 CFR Part 50 should meet the fracture toughness requirements of Appendix G as a supplement to the ASME Code requirements for fracture toughness.
    - c. Regulatory Guide 1.65 provides material specifications for reactor vessel closure studs. (Refer to SRP Section 5.3.1.)
    - d. Acceptable ASME Code Cases describing subjects related to fastener design and fastener materials are included in Regulatory Guides 1.84 and 1.85, respectively.

- e. Design practices should include consideration of information and recommendations in EPRI NP-5769, Volumes 1 and 2, as endorsed by Generic Letter 91-17 and NUREG-1339. Where the potential for degradation of threaded fasteners from borated water corrosion and/or stress-corrosion cracking exists, such degradation should be addressed in the design and minimized to the extent practical.
  - f. For those bolting applications subject to boric acid corrosion, an alloy resistant to boric acid and/or lithium hydroxide should be used. Alternatively, compatible coatings may be used on noncorrosion-resistant fasteners. An allowance for estimated loss of material due to corrosion may be incorporated in the design.
  - g. General guidance on the design of bolted mechanical (as opposed to structural) fasteners and joints may be found in standard textbooks such as Bickford (Ref. 29); EPRI NP-6316, "Guidelines for Threaded Fastener Applications"; and Volumes 1, 11, and 13 of the ASM Metals Handbook.
  - h. A matrix of bolting materials commonly used in nuclear power plants is contained in EPRI NP-6316.
  - i. Laboratory stress-corrosion tests and service experience indicate that cold-worked austenitic stainless steels used in the RCPB should be limited to materials with a yield strength of less than or equal to 621 MPa (90,000 psi).
3. Maintenance requirements should include the following:
- a. Inspection and testing should comply with Section XI, subsection IWB, of the ASME Code. The Code Cases listed in Regulatory Guide 1.147 provide additional guidance or alternatives acceptable to the staff.
  - b. The applicant should have systems and procedures to detect and correct leaks in the RCPB and to monitor the integrity of bolted joints.
  - c. The applicant's procedures for refurbishment, cleaning, replacement, and return-to-service should be reviewed with respect to mechanical fasteners.
  - d. Maintenance procedures should comply with EPRI NP-5067, Volume 1 or 2, as appropriate.
  - e. Additional guidance on acceptable maintenance practices can be found in EPRI NP-5769 (as endorsed in Generic Letter 91-17 and NUREG-1339) and in standard textbooks such as Bickford (Ref. 29).

- f. Where potential for degradation of threaded fasteners from borated-water corrosion and/or stress-corrosion cracking exists, such degradation should be addressed to the extent practical.<sup>28</sup>
- C. Acceptance criteria for threaded fastener applications in pressure-retaining joints of seismic Category I components other than the RCPB or RCS for areas of review described in subsection I.C include the following:
  - 1. General requirements for systems and components containing such fasteners are described in 10 CFR 50.55a and General Design Criteria 1, 2, and 4. Threaded fasteners in these applications are part of Quality Group B, C, and D components, as described in Regulatory Guide 1.26. Quality Group B and C fasteners must meet the specific requirements for ASME Code Class 2 or 3 components, respectively. Fasteners in Quality Group D components must meet the quality standards described in Table 1 of Regulatory Guide 1.26 for each specific application.
  - 2. Design requirements (including material selection and assurance of material compatibility) for threaded fasteners should include the following:
    - a. Design criteria for threaded fasteners should comply with the following industry standards (application of specific subsections and appendices of the ASME Code is summarized in EPRI NP-5769, Volume 2, Chapter 9):
      - (1) ASME Code Section III, Subsection NC (Class 2), for Quality Group B components;
      - (2) ASME Code Section III, Subsection ND (Class 3), for Quality Group C components;
      - (3) ASME Code Section VIII for Quality Group D pressure vessels;
      - (4) ANSI B31.1, "Power Piping," for Quality Group D piping and valves;
      - (5) API-650, "Welded Steel Tanks For Oil Storage"; AWWA D 100, "AWWA Standard For Welded Steel Elevated Tanks, Standpipes, and Reservoirs for Water Storage"; or ANSI B96.1, "American National Standard For Welded Aluminum-Alloy Storage Tanks," for Quality Group D atmospheric storage tanks; and
      - (6) API-620, "Design and Construction of Large, Welded, Low-Pressure Storage Tanks," for Quality Group D, 0-103 kPa (0-15 psig) rated storage tanks.
    - b. Code Cases describing subjects related to fastener design and materials are included in Regulatory Guides 1.84 and 1.85, respectively.

- c. Design practices should include consideration of information and recommendations in EPRI NP-5769, Volumes 1 and 2, as endorsed by Generic Letter 91-17 and NUREG-1339.
  - d. General guidance on the design of bolted mechanical (as opposed to structural) fasteners and joints can be found in standard textbooks such as Bickford (Ref. 29); EPRI NP-6316; and Volumes 1, 11, and 13 of the ASM Metals Handbook.
  - e. A matrix of bolting materials commonly used in nuclear power plants is contained in EPRI NP-6316.
3. Maintenance requirements should include the following:
- a. Inservice inspection and testing should be in accordance with ASME Code Section XI, Subsection IWC, for ASME Code Class 2 fasteners larger than 5.1 cm (2 in) in diameter. No specific provisions are offered in Section IWC or IWD of the ASME Code regarding inservice tests or inspections for Class 2 fasteners smaller than 5.1 cm (2 in) in diameter, Class 3 fasteners, and other seismic Category I fasteners.
  - b. The applicant should have systems and procedures to detect and correct leaks and to monitor the integrity of bolted joints.
  - c. The applicant's procedures for refurbishment, cleaning, replacement, and return-to-service should be reviewed.
  - d. Maintenance procedures should be in accordance with EPRI NP-5067, Volume 1 or 2, as appropriate.
  - e. Additional guidance on acceptable maintenance practices can be found in EPRI NP-5769 (as endorsed in Generic Letter 91-17 and NUREG-1339) and standard textbooks such as Bickford (Ref. 29).<sup>29</sup>
- D. Acceptance criteria for threaded fastener applications for nonpressure-retaining seismic Category I components, seismic Category I component supports, and seismic Category I structures for areas of review described in subsection I.C are as follows:
- 1. General requirements for SSCs containing such fasteners are described in 10 CFR 50.55a and General Design Criteria 1, 2, and 4, as outlined in subsection I.B.
  - 2. Design requirements (including material selection and assurance of material compatibility) should include the following:
    - a. ASME Code, Section III, Subsection NG, provides guidance for the design of core support structures, including threaded fasteners.

- b. ASME Code, Section III, Subsection NF, provides guidance for the design of ASME Code Class 1, 2, and 3 component supports, including threaded fasteners.
  - c. The ANSI/AISC N690-84 Code provides guidance for the design of threaded fasteners for joints in seismic Category I structures other than component supports or core support structures. The Manual of Steel Construction (published by the American Institute of Steel Construction, or AISC) provides acceptable data and details for design and installation of such structures.
  - d. Threaded fastener application for electrical equipment, other SSCs, or items otherwise not covered in a, b, or c, above, should conform to the manufacturer's plans and specifications and comply with sound engineering practices.
  - e. General guidance on the design of bolted mechanical (as opposed to structural) fasteners and joints is found in standard textbooks such as Bickford (Ref. 29); EPRI NP-6316; and Volumes 1, 11, and 13 of the ASM Metals Handbook.
  - f. To the extent practical, minimization of degradation and failure of support fasteners or embedments (e.g., resulting from fatigue, corrosion, inadequate installation, vibration, water hammer, or earthquake) should be emphasized in the design.
3. Maintenance requirements should include the following:
- a. The applicant should have procedures for refurbishment, cleaning, replacement, and return-to-service.
  - b. Maintenance procedures should be in accordance with EPRI NP-5067, Volume 1 or 2, as appropriate.
  - c. Additional guidance on acceptable maintenance practices can be found in EPRI NP-5769 (as endorsed in Generic Letter 91-17 and NUREG-1339) and standard textbooks such as Bickford (Ref. 29).
  - d. To the extent practical, minimization of degradation and failure of support fasteners or embedments (e.g., resulting from fatigue, corrosion, inadequate installation, vibration, water hammer, or earthquake) should be emphasized in the maintenance procedures.<sup>30</sup>
- E. Acceptance criteria for threaded fastener applications in SC I-related SSCs for areas of review described in subsection I.C are as follows:

1. General requirements for SSCs containing such fasteners are described in 10 CFR 50.55a and General Design Criteria 1, 2, and 4, as outlined in subsection I.B.
2. Design requirements (including material selection and assurance of material compatibility) should include the following:
  - a. Design should be in accordance with recognized codes and standards so that the function of seismic Category I SSCs will not be adversely affected by the failure of fasteners.
  - b. Section VIII of the ASME Code provides information on threaded fastener design applicable to Quality Group D components, as defined in Regulatory Guide 1.26.
  - c. General guidance on the design of bolted mechanical (as opposed to structural) fasteners and joints is found in standard textbooks such as Bickford (Ref. 29); EPRI NP-6316; and Volumes 1, 11, and 13 of the ASM Metals Handbook.
  - d. The AISC Manual of Steel Construction provides acceptable designs for structural connections.
  - e. To the extent practical, minimization of degradation and failure of support fasteners or embedments (e.g., resulting from fatigue, corrosion, inadequate installation, vibration, water hammer, or earthquake) should be emphasized in the design.
3. Maintenance requirements should include the following:
  - a. The applicant should have procedures for refurbishment, cleaning, replacement, and return-to-service.
  - b. Maintenance procedures should comply with EPRI NP-5067, Volume 1 or 2, as appropriate.
  - c. Additional guidance on acceptable maintenance practices can be found in EPRI NP-5769 (as endorsed in Generic Letter 91-17 and NUREG-1339) and standard textbooks such as Bickford (Ref. 29).
  - d. To the extent practical, minimization of degradation and failure of support fasteners or embedments (e.g., resulting from fatigue, corrosion, inadequate installation, vibration, water hammer, or earthquake) should be emphasized in maintenance practices.<sup>31</sup>



## Technical Rationale

The technical rationale for application of these acceptance criteria to review of threaded fasteners and associated design, installation, quality assurance, and maintenance program provisions is discussed in the following paragraphs.<sup>32</sup>

1. The requirements of 10 CFR 50.55a that are applicable to SSCs containing threaded fasteners are described in subsection I.B.1.

This SRP section describes the staff's review of threaded fasteners in the RCS and the RCPB, attached systems, component supports, other seismic Category I SSCs, and SSCs whose failure could affect seismic Category I SSCs (SC I-related). The codes and standards cited comply with the provisions of 10 CFR 50.55a and are commensurate with the safety functions to be performed.

Meeting the requirements of 10 CFR 50.55a provides assurance that threaded fasteners in SSCs that are important to safety will continue to perform their intended functions so that SSCs containing these fasteners are capable of performing their intended safety functions.<sup>33</sup>

2. The requirements of 10 CFR 50.60 that are applicable to systems and components containing threaded fasteners are described in subsection I.B.2.

This SRP section describes the staff's review of threaded fasteners in the RCS and RCPB. The requirements of 10 CFR 50.60 contain specific references to Appendix G to 10 CFR Part 50 regarding fracture toughness for components, including threaded fasteners.

Meeting the requirements of 10 CFR 50.60 and Appendix G to 10 CFR Part 50 provides assurance that fasteners in RCS and RCPB will continue to perform their intended functions so that SSCs containing these fasteners are capable of performing their intended safety functions.<sup>34</sup>

3. The requirements of GDC 1 that are applicable to SSCs containing threaded fasteners are described in subsection I.B.3.

This SRP section describes the staff's review of all threaded fasteners in SSCs important to safety, including a description of QA requirements. The standards cited are appropriate to the safety function of each SSC and commensurate with the safety function to be performed.

Meeting the requirements of GDC 1 provides assurance that fasteners important to safety will perform their intended functions so that SSCs containing these fasteners are capable of performing their intended safety functions.<sup>35</sup>

4. The requirements of GDC 2 that are applicable to SSCs containing threaded fasteners are described in subsection I.B.4.

This SRP section refers to the ASME, AISC, and other applicable codes to define allowable stresses in threaded fasteners. Loads are determined in the design of the components in which the threaded fasteners are installed, which in turn are designed in accordance with ASME, AISC, or other appropriate standards to withstand the effects of natural phenomena.

Meeting the requirements of GDC 2 provides assurance that fasteners important to safety are designed to resist the loads and conditions associated with natural phenomena, thereby performing their intended functions so that SSCs containing these fasteners are capable of performing their intended safety functions.<sup>36</sup>

5. The requirements of GDC 4 that are applicable to SSCs containing threaded fasteners are described in subsection I.B.5.

This SRP section refers to the ASME, AISC, and other applicable codes used to define allowable stresses in threaded fasteners. Loads are determined in the design of the components in which the threaded fasteners are installed, which in turn are designed in accordance with ASME, AISC, or other appropriate standards to withstand the effects associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs.

Meeting the requirements of GDC 4 provides assurance that fasteners important to safety are designed to resist the loads and conditions associated with normal operation, maintenance, testing, and postulated accidents, thereby performing their intended functions so that SSCs containing these fasteners are capable of performing their intended safety functions.<sup>37</sup>

6. The requirements of GDC 14 that are applicable to systems and components containing threaded fasteners are described in subsection I.B.6.

Threaded fasteners in the RCPB are to be designed, fabricated, and tested in accordance with Section NB of the ASME Code, which includes stringent requirements to ensure a low probability of failure or gross rupture of RCPB components.

Meeting the requirements of GDC 14 provides assurance that fasteners used in components of the RCPB will perform their intended function so that the RCPB is capable of remaining intact and preventing the spread of radioactive material.<sup>38</sup>

7. The requirements of GDC 15 that are applicable to systems and components containing threaded fasteners are described in subsection I.B.7.

Threaded fasteners in the RCS are to be designed, fabricated, and tested in accordance with Section NB of the ASME Code, which includes stringent requirements to ensure that the design conditions in fasteners used in the RCS are not exceeded during normal operation, including anticipated operational occurrences.

Meeting the requirements of GDC 15 provides assurance that fasteners used in components of the RCS will perform their intended function so that the RCS is capable of containing radioactive material with sufficient margin.<sup>39</sup>

8. The requirements of GDC 30 that are applicable to systems and components containing threaded fasteners are described in subsection I.B.8.

Threaded fasteners in the RCS are to be designed, fabricated, and tested in accordance with Section NB of the ASME Code, which includes stringent requirements to ensure that fasteners used in the RCS are designed, fabricated, installed, and tested to the highest quality standards practical. Leak detection systems are provided for the RCS.

Meeting the requirements of GDC 30 provides assurance that fasteners used in components of the RCS will perform their intended function so that the RCS is capable of remaining intact and preventing the spread of radioactive materials.<sup>40</sup>

9. The requirements of GDC 31 that are applicable to systems and components containing threaded fasteners are described in subsection I.B.9.

Threaded fasteners in the RCPB are to be designed, fabricated, and tested in accordance with Section NB of the ASME Code, which includes stringent fracture prevention requirements to ensure nonbrittle behavior of materials. The requirements of Appendix G to 10 CFR Part 50 regarding fracture prevention also apply to certain fasteners used in the RCPB. Further, Regulatory Guide 1.65 offers guidance with respect to the fracture toughness of reactor vessel closure studs. Material properties, temperature, operating conditions, radiation effects, varying stresses, and flaws are to be considered.

Meeting the requirements of GDC 31 provides assurance that fasteners used in components of the RCPB will perform their intended function so that the RCPB is capable of remaining intact and preventing the spread of radioactive materials.<sup>41</sup>

10. The requirements of GDC 32 that are applicable to systems and components containing threaded fasteners are described in subsection I.B.10.

Fasteners used in the RCPB are to be periodically inspected in accordance with Section IWB of the ASME Code. Surveillance includes consideration of material properties and leaktight integrity.

Meeting the requirements of GDC 32 provides assurance that fasteners used in components of the RCPB will perform their intended function so that the RCPB is capable of remaining intact and preventing the spread of radioactive materials.<sup>42</sup>

### III. REVIEW PROCEDURES

- A. Programs and procedures developed by the applicant are compared with the areas of review and acceptance criteria described above to determine that threaded fasteners included within the scope of this SRP section will perform their intended functions so that the SSCs using the fasteners are capable of performing their intended safety functions.
- B. At the operating license stage, programs, procedures, and records associated with the design, procurement, installation, inspection, quality assurance, maintenance, and failure analyses (if any) of threaded fasteners are reviewed by the staff.
- C. The reviewer selects and emphasizes material from the procedures described below, as appropriate. These review procedures are applicable to threaded fasteners and their applications as described in subsections I.C.1, I.C.2, and I.C.3:
  - 1. The loading and materials used in fasteners are compared with requirements of codes and standards acceptable to the staff. Areas of review, including those described in subsection I.C.4, are considered. Acceptance criteria for specific applications are described in subsection II.
  - 2. Programs and procedures developed by the applicant for installation, procurement, quality assurance, maintenance, and failure analysis of threaded fasteners are examined in accordance with the acceptance criteria in subsection II and the areas of review in subsection I.
    - a. The reviewer verifies that appropriate material and process controls are established and used for manufacturing components, constructing the reactor, and maintenance.
    - b. Procedures should provide for removal of all cleaning products, processing compounds, degreasing agents, and other foreign material before the component is subjected to elevated temperatures or pressure testing.
- D. If the information provided in the safety analysis report does not comply with the acceptance criteria, or if the information provided is inadequate to establish such compliance, a request for additional information is prepared and forwarded to the applicant. Such requests should identify the additional information required.<sup>43</sup>

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.<sup>44</sup>

#### IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided with respect to the areas of review and acceptance criteria described in this SRP section and that the review supports conclusions of the following type, to be included in the staff's safety evaluation report (SER):

1. The staff concludes that the applicant has met the requirements of 10 CFR 50.55a; 10 CFR 50.60; General Design Criteria 1, 2, 4, 14, 15, 30, 31, and 32; and the applicable provisions of Appendix B to 10 CFR Part 50 regarding threaded fasteners. The scope of the staff's review included programs and procedures developed by the applicant for threaded fasteners used in the RCPB, RCS, piping, machinery, equipment supports, structures, and SC I-related SSCs. Threaded fasteners were reviewed in accordance with this SRP section relative to their design, installation, procurement, quality assurance, maintenance, and failure analysis. The results of industry experience with fasteners have also taken into consideration by the applicant.
2. Use of these criteria as defined by applicable codes, standards, guides, specifications, and experience data provides reasonable assurance that fasteners used as specified in this SRP section will withstand expected forces and environmental conditions so that SSCs containing or supported by such fasteners are capable of performing their intended safety function.<sup>45</sup>

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.<sup>46</sup>

#### V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.<sup>47</sup> Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.<sup>48</sup>

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.<sup>49</sup>

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

## VI. REFERENCES

1. Regulatory Guide 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants."
2. Regulatory Guide 1.29, "Seismic Design Classification."
3. Regulatory Guide 1.36, "Nonmetallic Thermal Insulation For Austenitic Stainless Steel."
4. Regulatory Guide 1.65, "Materials and Inspections for Reactor Vessel Closure Studs."
5. Regulatory Guide 1.84, "Design and Fabrication Code Case Acceptability, ASME Section III, Division 1."
6. Regulatory Guide 1.85, "Materials Code Case Acceptability, ASME Section III, Division 1."
7. Regulatory Guide 1.147, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1."
8. Generic Letter 89-02, "Actions to Improve the Detection of Counterfeit and Fraudulently Marketed Products."
9. Generic Letter 91-05, "Licensee Commercial Grade Procurement and Dedication Programs."
10. NUREG-0943, "Threaded-Fastener Experience in Nuclear Power Plants."
11. NUREG-1339, "Resolution of Generic Safety Issue 29: Bolting Degradation or Failure in Nuclear Power Plants," June 1990.
12. EPRI NP-5067, "Good Bolting Practices - A Reference Manual for Nuclear Power Plant Maintenance Personnel, Volume I, Large Bolt Manual," Electric Power Research Institute, 1987.
13. EPRI NP-5067, "Good Bolting Practices - A Reference Manual for Nuclear Power Plant Maintenance Personnel, Volume II, Small Bolt Manual," Electric Power Research Institute, 1990.
14. EPRI NP-5652, "Guideline for the Utilization of Commercial-Grade Items in Nuclear Safety-Related Applications (NCIG-07), Electric Power Research Institute."

15. EPRI NP-5769, "Degradation and Failure of Bolting in Nuclear Power Plants," Volumes 1 and 2, Electric Power Research Institute, April 1988.
16. EPRI NP-6316, "Guidelines for Threaded-Fastener Applications in Nuclear Power Plants," Electric Power Research Institute, July 1989.
17. "AISC Manual of Steel Construction," American Institute of Steel Construction.
18. ANSI/AISC N690, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," American National Standards Institute and American Institute of Steel Construction.
19. ANSI B96.1, "American National Standard for Welded Aluminum-Alloy Storage Tanks," American National Standards Institute.
20. API Standard 620, "Design and Construction of Large, Welded, Low-Pressure Storage tanks," American Petroleum Institute.
21. API Standard 650, "Welded Steel Tanks for Oil Storage," American Petroleum Institute.
22. ASM Handbook Committee, "Metals Handbook," 9th Edition, American Society for Metals, 1978:

Volume 1, "Properties and Selection: Irons and Steels."

Volume 11, "Failure Analysis and Prevention."

Volume 13, "Corrosion."

23. ASME Boiler and Pressure Vessel Code, Section III, Division 1, "Nuclear Power Plant Components," American Society of Mechanical Engineers:

Subsection NB, "Class 1 Components."

Subsection NC, "Class 2 Components."

Subsection ND, "Class 3 Components."

Subsection NF, "Component Supports."

Subsection NG, "Core Support Structures."

Appendix I, "Design Stress Intensity Values, Allowable Stresses, Material Properties, and Design Fatigue Curves."

Appendix XI, "Rules for Bolted Flange Connections For Class 2 and 3 Components and Class MC Vessels."

Appendix XII, "Design Considerations for Bolted Flange Connections."

Appendix E, "Minimum Bolt Cross-Sectional Area."

Appendix Q, "Design Rules for Clamp Connections."

24. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, "Rules for the Construction of Pressure Vessels," American Society of Mechanical Engineers:

Subsection UG, "General Requirements."

Appendix 2, "Rules for Bolted Flange Connections."

Appendix S, "Design Considerations for Bolted Flange Connections."

Appendix Y, "Flat Face Flanges with Metal-to-Metal Contact Outside the Bolt Circle."

25. ASME Boiler and Pressure Vessel Code, Section XI, Division 1, "Rules for Inservice Inspection of Nuclear Power Plant Components," American Society of Mechanical Engineers.

26. ASME Boiler and Pressure Vessel Code, Section III, Division 2, "Code for Concrete Reactor Vessels and Containments (ACI Standard 359)," American Society of Mechanical Engineers and American Concrete Institute.

27. AWWA D100, "AWWA Standard For Welded Steel Elevated Tanks, Standpipes, and Reservoirs For Water Storage," American Water Works Association.

28. J. H. Bickford, "An Introduction to the Design and Behavior of Bolted Joints," Marcel Dekker, Inc., New York, 1981 (3rd Edition, 1995).<sup>50</sup>

29. 10 CFR Part 50, §50.55a, "Codes and Standards."<sup>51</sup>

30. 10 CFR Part 50, §50.60, "Acceptance Criteria For Fracture Prevention Measures For Lightwater Nuclear Power Reactors For Normal Operation."<sup>52</sup>

31. 10 CFR Part 50, Appendix A, "General Design Criteria,"<sup>53</sup>

General Design Criterion 1, "Quality Standards and Records,"

General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena,"

General Design Criterion 4, "Environmental and Dynamic Effects Design Bases,"

General Design Criterion 14, "Reactor Coolant Pressure Boundary,"



General Design Criterion 15, "Reactor Coolant System Design,"

General Design Criterion 30, "Quality of Reactor Coolant Pressure Boundary,"

General Design Criterion 31, "Fracture Prevention of Reactor Coolant Pressure Boundary," and

General Design Criterion 32, "Inspection of Reactor Coolant Pressure Boundary."

32. 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Facilities."<sup>54</sup>
33. 10 CFR Part 50, Appendix G, "Fracture Toughness Requirements."<sup>55</sup>
34. NRC Letter to all Holders of Operating Licenses or Construction Permits for Nuclear Power Plants, "Generic Safety Issue 29, Bolting Degradation or Failure in Nuclear Power Plants," October 17, 1991, (Generic Letter No. 91-17).<sup>56</sup>

## BIBLIOGRAPHY

## NRC Bulletins, Circulars, Generic Letters, and Notices

- DRAFT Rev. 0 - April 1996

NRC Notice 80-29 (Sup. 1)	Broken Studs on Terry Turbine Steam Inlet Flange (November 26, 1980)
NRC Notice 80-36	Failure of Steam Generator Support Bolting (October 10, 1980)
NRC Bulletin 82-02	Degradation of Threaded Fasteners in the Reactor Coolant Pressure Boundary (June 2, 1982)
NRC Notice 82-06	Failure of Steam Generator Primary Side Manway Studs (March 12, 1982)
NRC Notice 86-25	Traceability and Material Control of Fasteners (April 11, 1986)
NRC Notice 86-108	Degradation of Reactor Coolant System Pressure Boundary Resulting From Boric Acid Corrosion (December 29, 1986)
NRC Bulletin 87-02	Fastener Testing to Determine Conformance With Applicable Material Specifications (April 22, 1987)
NRC Bulletin 87-02 (Sup. 1)	Fastener Testing to Determine Conformance With Applicable Material Specifications (November 6, 1987)
NRC Bulletin 87-02 (Sup. 2)	Fastener Testing to Determine Conformance With Applicable Material Specifications (June 10, 1988)
NRC Notice 87-56	Improper Hydraulic Control Unit Installation At BWR Plants (November 4, 1987)
NRC Generic Letter 88-05	Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants (March 17, 1988)
NRC Notice 88-11	Potential Loss of Motor-Control Center Switchboard Function Due to Faulty Tie Bolts (April 7, 1988)
NRC Bulletin 89-02	Stress Corrosion Cracking of High-Hardness Type 410 Stainless Steel Internal Preloaded Bolting in Anchor Darling Model 350 Swing Check Valves or Valves of Similar Design (July 19, 1989)
NRC Generic Letter 89-02	Actions to Improve the Detection of Counterfeit and Fraudulently Marketed Products (March 21, 1989)
NRC Notice 89-22	Questionable Certification of Fasteners (March 3, 1989)
NRC Notice 89-59	Suppliers of Potentially Misrepresented Fasteners (August 16, 1989)

NRC Notice 89-70	Possible Indications of Misrepresented Vendor Products (October 11, 1989)
NRC Notice 90-68	Stress Corrosion Cracking of Reactor Coolant Pump Bolts (October 30, 1990)
NRC Generic Letter 91-05	Licensee Commercial Grade Procurement and Dedication Programs (April 9, 1991)
NRC Generic Letter 91-17	Generic Safety Issue 29, Bolting Degradation or Failure in Nuclear Power Plants (October 17, 1991)
NRC Notice 91-25	Commercial-Grade Structural Framing Components Supplied as Nuclear Safety-Related Equipment (April 1, 1991)
NRC Notice 95-12	Potentially Nonconforming Fasteners Supplied by A&G Engineering II, Inc. (February 21, 1995)

#### NRC NUREG Documents

NUREG-0943	Threaded-Fastener Experience in Nuclear Power Plants (January 1983)
NUREG-1095	Evaluation of Responses to IE Bulletin 82-02: Degradation of Threaded Fasteners in Reactor Coolant Pressure boundary of Pressurized-Water Reactor Plants (May 1985)
NUREG-1339	Resolution of Generic Safety Issue 29: Bolting Degradation or Failure in Nuclear Power Plants (June 1990)
NUREG-1349	Compilation of Fastener Testing Data Received in Response to NRC Compliance Bulletin 87-02 (June 1989)
NUREG-1445	Regulatory Analysis for the Resolution of Generic Safety Issue 29: Bolting Degradation or Failure in Nuclear Power Plants (September 1991)
NUREG/CR-3604	Bolting Applications (May 1984)
NUREG/CR-3766	Testing of Nuclear Grade Lubricants and Their Effect on A540 B24 and A193 B7 Bolting Materials (March 1984)
NUREG/CR-3963	Closeout of IE Bulletin 83-03: Check Valve Failures in Raw Water Cooling Systems of Diesel Generators (November 1986)

## Related Sections in the NRC Standard Review Plan, NUREG-0800

- 3.6.1 Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment
- 3.6.2 Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping
- 3.8.4 Other Seismic Category I Structures
- 3.9.2 Dynamic Testing and Analysis of Systems, Components, and Equipment
- 3.9.3 ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures
- 4.5.1 Control Rod Drive Structural Materials
- 4.5.2 Reactor Internal and Core Support Materials
- 5.2.3 Reactor Coolant Pressure Boundary Materials
- 5.3.1 Reactor Vessel Materials
- 5.4.2.1 Steam Generator Materials
- 6.1.1 Engineered Safety Feature Materials
- 6.2.7 Fracture Prevention of Containment Pressure Boundary
- 10.3.6 Steam and Feedwater System Materials

## NRC Regulatory Guides

- |                       |   |
|-----------------------|---|
| Regulatory Guide 1.26 | Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants |
| Regulatory Guide 1.29 | Seismic Design Classification   |
| Regulatory Guide 1.36 | Nonmetallic Thermal Insulation For Austenitic Stainless Steel   |
| Regulatory Guide 1.65 | Materials and Inspections for Reactor Vessel Closure Studs  |
| Regulatory Guide 1.84 | Design and Fabrication Code Case Acceptability, ASME Section III, Division 1  |
| Regulatory Guide 1.85 | Materials Code Case Acceptability, ASME Section III, Division 1   |

Electric Power Research Institute (EPRI) Publications

EPRI NP-5067	Good Bolting Practices - A Reference Manual for Nuclear Power Plant Maintenance Personnel, Volume I, Large Bolt Manual (1987)
EPRI NP-5067	Good Bolting Practices - A Reference Manual for Nuclear Power Plant Maintenance Personnel, Volume II, Small Bolt Manual (1990)
EPRI NP-5652	Guidelines for the Utilization of Commercial-Grade Items in Nuclear Safety-Related Applications (NCIG-07) (June 1988)
EPRI NP-5769	Degradation and Failure of Bolting in Nuclear Power Plants, Volumes 1 and 2 (April 1988)
EPRI NP-6316	Guidelines for Threaded-Fastener Applications in Nuclear Power Plants (July 1989)

Codes and Standards

ACI-349	Code Requirements for Nuclear Safety Related Concrete Structures, American Concrete Institute
ANSI B31.1	Power Piping, American National Standards Institute
ANSI B96.1	American National Standard For Welded Aluminum-Alloy Storage Tanks, American National Standards Institute
ANSI/AISC N690	Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, American National Standards Institute and American Institute of Steel Construction
API Standard 620	Design and Construction of Large, Welded, Low-Pressure Storage Tanks, American Petroleum Institute
API Standard 650	Welded Steel Tanks for Oil Storage, American Petroleum Institute
ASME B1.1	Unified Inch Screw Threads (UN and UNR Thread Form), An American National Standard, American Society of Mechanical Engineers
ASME B1.2	Gages and Gaging for unified Inch Screw Threads, An American National Standard, American Society of Mechanical Engineers
ASME B1.3M	Screw Thread gaging systems for Dimensional Acceptability - Inch and Metric Screw Threads (UN, UNR, UNJ, M, and MJ), An

American National Standard, American Society of Mechanical Engineers

ASME Code      Section III, Division 1, Nuclear Power Plant Components, American Society of Mechanical Engineers:

Subsection NB, Class 1 Components

Subsection NC, Class 2 Components

Subsection ND, Class 3 Components

Subsection NF, Component Supports

Subsection NG, Core Support Structures

Appendix I, Design Stress Intensity Values, Allowable Stresses, Material Properties, and Design Fatigue Curves

Appendix XI, Rules for Bolted Flange Connections For Class 2 and 3 Components and Class MC Vessels

Appendix XII, Design Considerations for Bolted Flange Connections

Appendix E, Minimum Bolt Cross-Sectional Area

Appendix Q, Design Rules for Clamp Connections

ASME Code      Section VIII, Division 1, Rules for the Construction of Pressure Vessels:

Subsection UG, General Requirements

Appendix 2, Rules for Bolted Flange Connections

Appendix S, Design Considerations for Bolted Flange Connections

Appendix Y, Flat Face Flanges with Metal-to-Metal Contact Outside the Bolt Circle

ASME Code      Section XI, Division 1, Rules for Inservice Inspection of Nuclear Power Plant Components

ASME Code      Section III, Division 2, Code for Concrete Reactor Vessels and Containments (ACI Standard 359), American Society of Mechanical Engineers and American Concrete Institute

AWWA D100

AWWA Standard For Welded Steel Elevated Tanks, Standpipes,  
and Reservoirs For Water Storage, American Water Works  
Association

No designation

Manual of Steel Construction, American Institute of Steel Construction

Texts and Papers

ASM Handbook Committee, "Metals Handbook," 9th Edition, American Society for  
Metals (1978):

Volume 1, "Properties and Selection: Irons and Steels"

Volume 11, "Failure Analysis and Prevention"

Volume 13, "Corrosion"

J. H. Bickford, "An Introduction to the Design and Behavior of Bolted Joints,"  
Marcel Dekker, Inc., New York (1981) (3rd Edition, 1995)

J. M. Jenco, Advisor, "NMAC Good Bolting Practices Workshop and Technology Exhibition,"  
Nuclear Maintenance Applications Center of the Electric Power Research Institute  
(EPRI/NMAC), Westin Galleria Hotel, Houston, Texas, September 8-10, 1993

G. L. Kulak, J. W. Fisher, and J. H. A. Struik, "A Guide to Design Criteria For Bolted and  
Riveted Joints," John Wiley & Sons, New York (1987)

E. A. Merrick and M. Prager, Eds., "Improved Technology for Critical Bolting Applications,"  
MPC-Vol. 26, Papers presented at the 1986 Pressure Vessels and Piping Conference and  
Exhibition, Chicago, IL, July 20-24, 1986, American Society of Mechanical Engineers (1986)

P. M. Toor, Ed., "Structural Integrity of Fasteners," STP 1236, Papers from Symposium on  
Structural Integrity of Fasteners, Miami, FL, November 16-19, 1992, American Society for  
Testing and Materials (1995)<sup>57</sup>



**SRP Draft Section 3.13**  
Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Integrated Impact No. 1425	A new SRP section on threaded fasteners was added as part of the resolution of Generic Safety Issue (GSI) 29, as described in Generic Letter 91-17 and NUREG-1339.
2.	Integrated Impact No. 1425. Purpose of the review	Summarized the purpose of the review as outlined in the resolution of GSI 29 and previous drafts and outlines of the SRP section, as provided by the staff.
3.	Integrated Impact No. 1426. 10 CFR 50.55a requirements related to the areas of review for threaded fasteners	Summarized those requirements of 10 CFR 50.55a pertaining to the design, fabrication, inspection, and testing of threaded fasteners. 10 CFR 50.55a refers to industry codes and standards applicable to the areas of review.
4.	Integrated Impact No. 1427. 10 CFR 50.60 requirements related to the areas of review for threaded fasteners	Summarized those requirements of 10 CFR 50.60 pertaining to the design of threaded fasteners in pressure retaining components of the reactor coolant pressure boundary (RCPB).
5.	Integrated Impact No. 1428. General Design Criterion (GDC) 1 requirements related to the areas of review for threaded fasteners	Summarized the design criteria of GDC 1 pertaining to the quality standards and records applicable to threaded fasteners used in safety related applications.
6.	Integrated Impact No. 1429. GDC 2 requirements related to the areas of review for threaded fasteners	Summarized the design criteria of GDC 2 pertaining to the loads and forces that are imposed on threaded fasteners used in safety related applications.
7.	Integrated Impact No. 1429. GDC 4 requirements related to the areas of review for threaded fasteners	Summarized the design criteria of GDC 4 pertaining to the environmental conditions including dynamic loads that are imposed on threaded fasteners used in safety related applications.
8.	Integrated Impact No. 1430. GDC 14 requirements related to the areas of review for threaded fasteners	Summarized the design criteria of GDC 14 pertaining to the special requirements and conservative margins for components, including fasteners, located within the RCPB.
9.	Integrated Impact No. 1430. GDC 15 requirements related to the areas of review for threaded fasteners	Summarized the design criteria of GDC 15 pertaining to the margins required for reactor coolant system (RCS) components, including threaded fasteners.

**SRP Draft Section 3.13**  
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
10.	Integrated Impact No. 1430. GDC 30 requirements related to the areas of review for threaded fasteners	Summarized the design criteria of GDC 30 pertaining to the quality standards to be maintained for components of the RCPB, including threaded fasteners.
11.	Integrated Impact No. 1430. GDC 31 requirements related to the areas of review for threaded fasteners	Summarized the design criteria of GDC 31 pertaining to the material properties and fracture prevention requirements applicable to components of the RCPB, including threaded fasteners.
12.	Integrated Impact No. 1430. GDC 32 requirements related to the areas of review for threaded fasteners	Summarized the requirements of GDC 32 pertaining to the material surveillance and inspections of RCPB components, which are related to threaded fasteners.
13.	Integrated Impact No. 1428. Appendix B of 10 CFR 50 requirements related to the areas of review for threaded fasteners	Summarized the quality assurance requirements of Appendix B to 10 CFR 50 applicable to safety related components, including threaded fasteners.
14.	Integrated Impact No. 1425. Regulatory Guide 1.29	Described scope of review of threaded fasteners in seismic Category I as well as seismic Category I-related (SC-I related) structures, systems, and components (SSCs).
15.	Integrated Impact No. 1425. Generic Letter 91-17, NUREG-1339, EPRI NP-5769, and EPRI NP-6316	Listed threaded fasteners covered by this SRP section. Fasteners were categorized as (a) those threaded fasteners in the RCS or within the RCPB, (b) those threaded fasteners in seismic Category I pressure retaining components outside the RCPB, (c) those threaded fasteners in seismic Category I nonpressure-retaining components, supports, and structures, and (d) those threaded fasteners in SC-1 related SSCs.
16.	Integrated Impact No. 1425. Generic Letter 91-17, NUREG-1339, EPRI NP-5067, EPRI NP-5769, and EPRI NP-6316	Listed those subjects that are reviewed for each threaded fastener application. Those subjects are (a) design, (b) installation, (c) procurement, (d) quality assurance, (e) maintenance, (f) failure analysis, and (g) duties of an individual assigned as a threaded fastener engineer.
17.	Integrated Impact No. 1425. Generic Letter 91-17, NUREG-0943, NUREG-1339, and EPRI NP-5769	An area of review regarding threaded fastener failure experience is included.
18.	Integrated Impact No. 1425. NUREG-0800	Made reference to coordination of related reviews which are covered in other SRP sections.
19.	Editorial	Added paragraph to refer to the bibliography.

**SRP Draft Section 3.13**  
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
20.	SRP-UDP format item	Added "Review Interfaces" sub-heading and lead-in sentence.
21.	Integrated Impact No. 1425.	Listed the review responsibilities of the EMCGB related to the review of threaded fastener applications.
22.	Integrated Impact No. 1425.	Listed the review responsibilities of the ECGB related to the review of threaded fastener applications.
23.	Integrated Impact No. 1425.	Listed the review responsibilities of the EMEB related to the review of threaded fastener applications.
24.	Integrated Impact No. 1425.	Listed the review responsibilities of the HQMB related to the review of threaded fastener applications.
25.	SRP-UDP format item	Included standard paragraph regarding relationship of the areas of review to the acceptance criteria and review procedures in other SRP sections.
26.	PRB Comment	This paragraph was provided as a PRB comment during final section integration.
27.	Integrated Impact No. 1425. Generic Letter 91-17, Regulatory Guide 1.36, NUREG-0943, NUREG-1339, EPRI NP-5067, EPRI NP-5769, and EPRI NP-6316	Described acceptance criteria that is generally applicable to all threaded fasteners covered by this SRP section. These general acceptance criteria cover (1) installation, (2) procurement and quality assurance, (3) failure analysis, and (4) compatibility of austenitic stainless steel materials with thermal insulation.
28.	Integrated Impact Nos. 1425-1430. 10 CFR 50.55a, 10 CFR 50.60, GDC 1, 2, 4, 14, 15, 30, 31, and 32, Appendix G to 10 CFR 50, Regulatory Guides 1.26, 1.65, 1.84, 1.85, and 1.147, Generic Letter 91-17, NUREG-0943, NUREG-1339, Section III and XI of the ASME Code, EPRI NP-5067, EPRI NP-5769, and EPRI NP-6316	Described acceptance criteria applicable to threaded fasteners in the RCPB and RCS as provided in the source documents.
29.	Integrated Impact Nos. 1425, 1426, 1428, and 1429. 10 CFR 50.55a, GDC 1,2, and 4, Regulatory Guide 1.26, 1.84, and 1.85, Generic Letter 91-17, NUREG-1339, Section III, VIII, and XI of the ASME Code, EPRI NP-5067, EPRI NP-5769, EPRI NP-6316, API-620, API-650, AWAA D 100, ANSI B31.1, and ANSI B96.1	Described acceptance criteria applicable to threaded fasteners in pressure retaining components outside the RCPB.

**SRP Draft Section 3.13**  
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
30.	Integrated Impact Nos. 1425, 1426, 1428, and 1429. 10 CFR 50.55a, GDC 1, 2, and 4, Section III of the ASME Code, ANSI/AISC N690-84, EPRI NP-5067, EPRI NP-5769, EPRI NP-6316, the ASM Metals Handbook, and the AISC Steel Construction Manual	Described acceptance criteria applicable to threaded fasteners in seismic Category I nonpressure-retaining components, seismic Category I component supports, and seismic Category I structures.
31.	Integrated Impact Nos. 1425, 1426, 1428, and 1429. 10 CFR 50.55a, GDC 1,2, and 4, Regulatory Guide 1.26, EPRI NP-5067, EPRI NP-5769, EPRI NP-6316, the ASM Metals Handbook, and the AISC Steel Construction Manual	Described acceptance criteria applicable to threaded fasteners in SC-I related SSCs.
32.	SRP-UDP format item	Added "Technical Rationale" sub-heading and lead-in sentence.
33.	SRP-UDP format item	Added technical rationale for 10 CFR 50.55a.
34.	SRP-UDP format item	Added technical rationale for 10 CFR 50.60 and Appendix G of 10 CFR 50.
35.	SRP-UDP format item	Added technical rationale for GDC 1.
36.	SRP-UDP format item	Added technical rationale for GDC 2.
37.	SRP-UDP format item	Added technical rationale for GDC 4.
38.	SRP-UDP format item	Added technical rationale for GDC 14.
39.	SRP-UDP format item	Added technical rationale for GDC 15.
40.	SRP-UDP format item	Added technical rationale for GDC 30.
41.	SRP-UDP format item	Added technical rationale for GDC 31.
42.	SRP-UDP format item	Added technical rationale for GDC 32.
43.	Integrated Impact No. 1425.	Incorporated standard review procedures to cover areas of review and acceptance criteria.
44.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.

**SRP Draft Section 3.13**  
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
45.	Integrated Impact No. 1425.	Incorporated examples of evaluation findings based on the areas of review, acceptance criteria, and review procedures in this SRP section.
46.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items relevant to the SRP section.
47.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
48.	Integrated Impact No. 1425.	Included standard implementation instructions.
49.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
50.	Integrated Impact No. 1425.	Included references to reflect text of the SRP section.
51.	SRP-UDP format item	Added reference listing for regulations cited in the section.
52.	SRP-UDP format item	Added reference listing for regulations cited in the section.
53.	SRP-UDP format item	Added reference listing for regulations cited in the section.
54.	SRP-UDP format item	Added reference listing for regulations cited in the section.
55.	SRP-UDP format item	Added reference listing for regulations cited in the section.
56.	SRP-UDP format item	Added reference listing for a Generic Letter that is central to the section and that is cited in the section.
57.	Integrated Impact No. 1425.	Included a bibliography to cover pertinent background material for the convenience of the reviewer.

[This Page Intentionally Left Blank]

**SRP Draft Section 3.13**  
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
1425	Provide new SRP section on threaded fasteners	All of SRP Section 3.13
1426	Cite 10 CFR 50.55a in SRP Section 3.13	AREAS OF REVIEW; subsection I.B.1  ACCEPTANCE CRITERIA; first sentence of Section II, subsection II.B, subsection II.C.1, subsection II.D, subsection II.E  Technical Rationale; subsection II.1  EVALUATION FINDINGS; subsection IV.1
1427	Cite 10 CFR 50.60 and Appendix G of 10 CFR 50 in SRP Section 3.13	AREAS OF REVIEW; subsection I.B.2  ACCEPTANCE CRITERIA; first sentence of Section II, subsection II.B.2.b, subsection II.C.1  Technical Rationale; subsection II.2  EVALUATION FINDINGS; subsection IV.1
1428	Cite GDC 1 and Appendix B of 10 CFR 50 in SRP Section 3.13 for review and for interfacing review by the HQMB	AREAS OF REVIEW; subsection I.B.3 and I.B.11, I.C.4.d, I.C.4.f,  Review Interfaces; subsection I.6  ACCEPTANCE CRITERIA; first sentence of subsection II, subsection II.A.2, subsection II.A.3,  Technical Rationale; subsection II.3  REVIEW PROCEDURES, subsection III.B  EVALUATION FINDINGS, subsection IV.1
1429	Cite GDC 2 and GDC 4 for design bases for threaded fastener applications	AREAS OF REVIEW; subsection I.B.4, subsection I.B.5, subsection I.C.6  ACCEPTANCE CRITERIA; subsections II.B., II.C, II.D, and II.E  Technical Rationale; subsections II.4, and II.5  EVALUATION FINDINGS; subsection IV.1

**SRP Draft Section 3.13**  
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
1430	Cite GDCs 14, 15, 30, 31, and 32 for applications of threaded fasteners within the RCPB or in the RCS.	AREAS OF REVIEW; subsections I.B.6 through I.B.10  ACCEPTANCE CRITERIA; first sentence of Section II, subsection II.B.1,  Technical Rationale; subsections II.6 through II.10  EVALUATION FINDINGS; subsection IV.1